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RADIOPHYSICAL CHARACTERISTICS OF A RADIATOR BASED ON A GAS DISCHARGE PLASMA

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ABSTRACT

The results of the study of characteristics of a microwave radiator based on cold plasma of a gas disharge are presented. A method of determining the plasma conductivity in the given frequency band is proposed and discussed.

As plasma always contains free charges (electrons and ions, see [1]), its excitation by a source of alternating voltage results in appearance of alternating current. For a certain electrical size of plasma segments this leads to the radiation of time-varying electromagnetic field [2].

Experimental research of a loop radiator based on cold plasma of a gas discharge [3] has shown that the bandwidth properties of its radiation characteristics and input impedance considerably exceed those of antenna based on conductors of similar configuration.

For a physical substantiation of this phenomenon we should take into account that the concentration of free carriers in gas-discharge plasma is approximately 7 orders smaller than their concentration in metals [1]. Therefore, in a plasma radiator (PR) the resistance to current exited by an external microwave field is much greater than in a conductor, especially in a perfect one. This results in the attenuation of a wave of current reflected from the end of PR antenna, establishment of a mode close to a traveling wave, and hence to stabilization of the input impedance and radiation characteristics of PR in a wider frequency band.

PR can be considered as an imperfect conductor with continuously distributed impedance along its length.

We are interested in estimation of conductivity of a PR shaped as a pole of plasma by using experimental values of input impedances PR obtained in [3] according to the following technique:

1) Excite, in the frequency band 150-350 *MHz*, the studied volume (configuration) of plasma and measure the set of values of the input impedance $Z_{pl}(f)$ of the radiator in this range,
2) Solve, in accurate formulation, the problem about the distribution of current and find the input impedance $Z_{cl}(f,\sigma)$ of PR with finite and varying values of conductivity σ,
3) Solve the problem of optimization of σ variation by using the criterium of a minimum of objective function $Z(\sigma)$ in the given frequency band:

$$\min Z(\sigma) \tag{1}$$

$$f \in [150;350]\,MHz; \quad \sigma \in (\sigma_1, \sigma_2)$$

In accordance to the above mentioned techniques, we solved the problem of optimization, where the following functions were chosen as the objective ones:

$$Z_1(\sigma) = \sqrt{\frac{\sum_{j=1}^{N} \left[K_{pl}(f_j) - K_{cl}(f_j, \sigma)\right]^2}{\sum_{j=1}^{N} K_{pl}^2(f_j)}}, \tag{2}$$

$$Z_2(\sigma) = \frac{1}{N}\sqrt{\sum_{j=1}^{N}\left[\frac{K_{pl}(f_j) - K_{cl}(f_j, \sigma)}{K_{pl}(f_j)}\right]^2}, \tag{3}$$

$$Z_3(\sigma) = \frac{1}{N}\sum_{j=1}^{N}\left[\frac{K_{pl}(f_j) - K_{cl}(f_j, \sigma)}{K_{pl}(f_j)}\right]^2, \tag{4}$$

$$Z_4(\sigma) = \frac{1}{N}\sum_{j=1}^{N}\left|\frac{K_{pl}(f_j) - K_{cl}(f_j, \sigma)}{K_{pl}(f_j)}\right|, \tag{5}$$

where N is the total number of discrete frequencies in the given band, i is the number of the frequency value in the given band, $K_{pl}(f_i)$ and $K_{cl}(f_i, \sigma)$ are experimental and calculated values of the voltage standing wave ratio (VSWR) in the given frequencies, respectively.

The values of VSWR were measured and calculated in the range of 150 to 350 *MHz* with the interval of 10 *MHz*. The calculations of objective functions (2), (3), (4) and (5) in the given frequency band were performed with MATLAB. Here, 29 computed values, K_{cl}, for the conductivities in the range of $0 < \sigma \leq 20\,Sm$ were examined.

The results of calculations are presented as plots in Fig. 1, where the curves are numbered in accordance to the numbers of objective functions (5). From these plots, we can see that all the studied objective functions display global minima at values of conductivity approximately equal to 0,5 – 0,6 *Sm*.

The studied PR attracts an interest of microwave researchers since it allows to combine radiation of electromagnetic power in considerably different frequency bands:

optical and microwave. Agreement between the values of optimal conductivity of PR found during optimization with different objective functions proves a reliability of the obtained results.

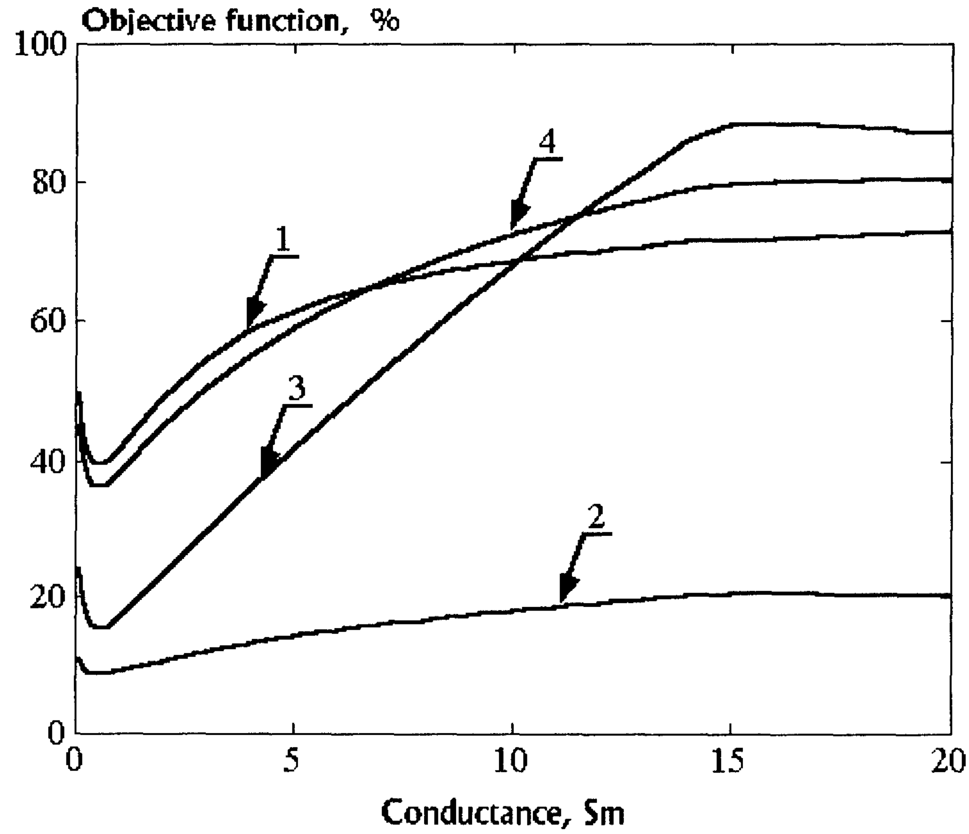

Fig.1. Objective function versus conductivity of plasma of PR

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